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DECEMBER, 1962

DEFENSE METALS INFORMATION CENTER

SELECTED ACCESSIONS

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Compiled by:

Patricia B. Plate

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HIGH-STRENGTH ALLOYS

49290 SHEET METAL FORMING TECHNOLOGY. W. W. Wood, R. E. Goforth, D. L. Norwood, C. H. Cole, Jr., W. D. Moore, C. R. Clifton, J. R. Russell, W. A. Beck, R. A. Ford, and B. L. Scott, Chance Vought Corporation, Dallas, Texas. ASD TR 7-871 (III), Interim Technical Engineering Report, September 1962, Contract No. AF 33(657)-7314
(2 references, 203 pages, 53 figures, 38 tables)

The purpose of this project is to determine the inherent limitations of sheet metal forming processes, to develop the knowledge to significantly advance these, and to recommend the manner in which this can be accomplished. Principal areas of investigation are concerned with the effect that primary process variables such as velocity, temperature, and pressure have on various classes of metals and alloys.

49387 ADVANCES IN THE CONTINUOUS CASTING OF STEEL. Industrial Heating, v. 29, no. 7, July 1962, p. 1283-1284, 1286, 1288, 1290 & 1292
(6 pages)

Great strides have been made in the development and perfection of the continuous casting of steel. The extent and nature of these developments are reported in this article, which is comprised of abstracts of papers, sponsored by the Institute of Metals Division, presented during the 1961 Fall Meeting of the Metallurgical Society of AIME, in Detroit.

49468 FRACTURE MECHANICS RESEARCH AT LEHIGH UNIVERSITY, 1960-61. L. Y. Bahar, F. P. Beer, F. Erdogan, P. C. Paris, G. C. Sih, and O. Tuncel, Lehigh University, Bethlehem, Pennsylvania. D6-7960, (Received November, 1962), Report
(89 pages, numerous figures, numerous tables)

This is a compilation of fracture mechanics research. The work covered includes:

(1) Application of Muskhelishvili's methods to the analysis of crack tip stress intensity factors for plane problems
(2) Crack-tip stress-intensity factors for transverse bending of plates and some thermal stress problems.

49468 (Continued)

(3) Crack-tip stress-intensity factors for torsion and flexure of cylindrical bars
(4) Stress-intensity factors by dimensional analysis
(5) The stress-distribution in an infinite plate with two co-linear cracks subjected to arbitrary loads in its plane

(6) An approach to the study of crack growth under random loadings
(7) The stress distribution in an infinite plate with a straight cut subjected to concentrated loads and couples in its plane
(8) The stress distribution and stress-intensity factors for a crack tip in an anisotropic plate subjected to extension
(9) The singular character of thermal-stresses near a crack tip.

49472 AN EXPERIMENTAL INVESTIGATION OF THE CRACK TIP STRESS INTENSITY FACTORS IN PLATES UNDER CYLINDRICAL BENDING. F. Erdogan and O. Tuncel, Lehigh University, Bethlehem, Pennsylvania. August 1962, Interim Report, for Boeing Company
(12 references, 29 pages, 25 figures, 20 tables)

This experimental study was undertaken to investigate the validity of the theory based on the crack-tip stress-intensity factors to explain the fracture of thin cracked plates subjected to static bending moments.

The results indicate that there is in fact a critical value of the stress-intensity factor, which is proportional to the external loads and to the square root of the crack length, at which the crack starts growing. The results also lead to two main conclusions: first, the external load (here, the bending moment) which starts the crack growing is not sufficient for the fracture of the plate if it is maintained constant; second, the critical values of the stress-intensity factors in bending and in tension for the same material are not equal and, depending on the thickness of the plate, the critical-stress-intensity factor for bending can be as high as 2 to 3 times that for tension.

49509 IDENTIFICATION OF MICROCONSTITUENTS IN SUPERALLOYS. C. H. Lund and H. J. Wagner, Battelle Memorial Institute, Columbus, Ohio. DMIC Memorandum 160, November 15, 1962
(41 references, 22 pages)

The superalloys enjoy an established position as structural materials within the temperature range of about 1300 to 1950 F. The excellent strength properties of these alloys within that temperature range are due to the combined effects of solid-solution strengthening, precipitation-hardening, and, to some extent, dispersion hardening. The strengthening mechanism by which these elements improve the long-time properties of these alloys is not fully understood.

For strength between 1300 and 1950 F, the nickel-base superalloys currently in use depend to a great extent upon the precipitation of a second phase. Solid-solution strengthening and dispersion hardening also contribute but are secondary in those temperature ranges in which the precipitated second phase is operative.

This memo explores the effect of microconstituents in superalloys.

49520 CRYOGENIC EMITTANCE MEASUREMENTS. R. P. Caren, Lockheed Missiles & Space Company, Palo Alto, California. Preprint of paper, v. 5, presented by ASD, National Bureau of Standards & NASA, Dayton, Ohio, September 5-7, 1962
(6 references, 16 pages, 1 figure)

No measurements have been amde of the emissivities of materials at temperatures below 77 K. The described apparatus has been designed so that measurements can be made from a temperature range 10 K to 300 K. The measurements are made calorimetrically by measuring the temperature decay of the sample during given time intervals. The specific heat, mass, and surface area must be known in order to compute the emissivity.

49534 See Applications.

Nickel Base

49274 See Applications.

49279 CREEP-RUPTURE PROPERTIES OF SIX ELEVATED TEMPERATURE ALLOYS. J. G. McBride, B. Mulhern, and R. Wilmer, New England Materials Laboratory, Inc., Medford, Massachusetts. WADD TR 61-199, August 1962, Contract No. AF 33(616)-6200 (66 pages, 36 figures, 25 tables)

Room-temperature tensile properties, short-time elevated-temperature properties, and elevated-temperature creep-rupture properties were determined for six widely used elevated-temperature alloys. Representative commercial lots of Udimet 700 (Bar), GMR-235 (Cast Bar), Rene '41 (Sheet), R-235 (Sheet), and Nicrotung (Cast Bar) were tested at each of three typical application temperatures. Tabulated tensile and creep-rupture data, stress-versus-rupture-life curves, creep-versus-time curves, and stress-versus-time to 0.2 per cent and 1.0 per cent total-creep curves are presented.

49283 OXIDE BONDING AND THE CREEP-RUPTURE STRENGTH OF NICKEL. T. R. Cass and M. R. Achter, U. S. Naval Research Laboratory, Washington, D. C. NRL Report 5803, June 22, 1962
(9 references, 9 pages, 7 figures)

A technique for measuring the creep and rupture strength of nickel specimens bonded by sintered-oxide layers has been developed. This technique is used in the investigation of the role of grain-boundary oxide in the oxidation strengthening of nickel during creep at 817 C. From the inverse dependence of the rate of bonding on the thickness of the starting oxide, it is suggested that the rate of diffusion of Ni^{++} through NiO is the controlling process at the start of sintering. Comparisons of the creep and rupture strength and of the microstructure of sintered couples with conventional creep specimens suggest that rupture in nickel is prevented by load-bearing intergranular layers of oxide.

49291 HOT HARDNESS OF ELECTROLESS NICKEL COATINGS. K. T. Ziehlke, Union Carbide Corporation, Union Carbide Nuclear Company, Oak Ridge, Tennessee. K-1460, AEC Research & Development Report, October 10, 1962, Contract No. W7405-eng-26
(5 references, 11 pages, 5 figures, 1 table)

The hardness of heat-treated, electroless nickel coatings was measured at temperatures from 75 F to 1000 F. The effects of phosphorus content from 6.8 to 10.5 weight per cent on both hot hardness and physical structure were determined.

Temperatures to 700 F have a moderate effect on the coatings, which have useful hardnesses if that temperature is not exceeded. The interrelationship of hardness and temperature from 75 to 700 F is shown in a nomogram, from which the hardness at any temperature can be determined if the hardness at any other temperature is known.

49475 See Engineering Steels.

49497 See Engineering Steels.

49509 See High-Strength Alloys.

49515 See Coatings.

Engineering Steels

49240 MASS EFFECT ON TENSILE PROPERTIES OF HIGH STRENGTH STEEL CASTINGS. P. J. Ahearn, Watertown Arsenal Laboratories, Watertown, Massachusetts. WAL TR 320.1/9, September 1962
(8 references, 15 pages, 7 figures, 1 table)

The effect of mass on the tensile properties of high strength (about 240,000 psi tensile strength) steel was determined by tests on specimens removed from a 6-inch-square and an 8-inch-diameter cast coupon. The steel employed was a modified 4330 steel with low sulfur and phosphorus contents. In addition to true stress-true strain tensile tests, metallographic and microradiographic studies were conducted to investigate the cause of this mass effect.

49268 EVALUATION OF COATING SYSTEMS FOR HIGH STRENGTH, LOW ALLOY STEEL EXTERIOR MISSILE AND ROCKET CASINGS. H. R. Nelson and K. E. Hofer, Armour Research Foundation of Illinois Institute of Technology, Chicago, Illinois. ASD TDR 62-421, May 1962, Contract No. AF 33(616)-7739
(61 pages, 24 figures, 12 tables)

Existing coating systems were evaluated by exposing coated-metal specimens to environments to which missile and rocket casings may be exposed during fabrication, storage, shipment, and readiness. SAE 4340 steel was the substrate material. The protection afforded the substrate was evaluated by direct tests of the coatings or by the change in the performance of the coating or substrate following exposure to various adverse environments.

Sixteen coating systems were studied. Tension, fatigue, embrittlement, abrasion, adhesion, flexibility, stress-corrosion, thermal change and humidity, accelerated weathering, and salt spray corrosion were the tests made.

49272 INVESTIGATION OF THE EFFECTS OF MELTING PROCESSES UPON THE TRANSVERSE DUCTILITY OF H-11 STEEL AT HIGH STRENGTH LEVELS. J. C. Truszynski and J. A. Yoblin, Ladish Company, Cudahy, Wisconsin. ASD TR 7-678 (III), Interim Engineering Report No. 3, October 1962, Contract No. AF 33(600)-38767
(36 references, 58 pages, 6 figures, 7 tables)

Recent developments in steel melting and solidification practice are reported upon in order to update the Phase I literature survey. The Phase II statistical analysis of transverse strength and ductility in ultrahigh-strength H-11 steel processed by air melting and by vacuum-arc remelting is summarized. The four vacuum-arc-remelt process variations selected for investigation in Phase III are discussed and metallurgical requirements for this material are specified.

49275 TENSILE PROPERTIES OF EXPLOSIVELY FORMED MILD-STEEL PLATE. E. A. Lange, T. W. Crooker, and E. P. Klier, U. S. Naval Research Laboratory, Washington, D. C. NRL Report 5819, September 18, 1962
(8 references, 22 pages, 21 figures, 3 tables)

49275 (Continued)

In the present investigation four samples of 1/2-inch-thick mild-steel plate were explosively formed through a central-hole die into circular bulges. Specimens from the bulge, the die-edge region, and the plate edge were taken from each plate, and stress-strain relationships were determined from these specimens.

At all locations on each plate, the increase in both yield strength and tensile strength is significant. The explosively induced strain, however, has a greater effect on yield strength than on nominal tensile, strength, the maximum potential increases being approximately 100 and 50 per cent, respectively. The forming strain at these maximum levels of strength causes only a 30 per cent decrease in the reduction in area. For the mild-steel plates used in this investigation, high values of forming strains increased the nominal tensile strength from 50,000 psi to 75,000 psi. It was found that the terminal strain from explosive loading is equal to the terminal strain in a conventional tensile test. Also, residual macrostresses in explosively formed mild steel are nil.

49321 LOW-CYCLE AXIAL FATIGUE BEHAVIOR OF MILD STEEL. J.T.P. Yao and W. H. Munse, University of New Mexico, Alburquerque, New Mexico and University of Illinois, Urbana, Illinois. Paper No. 45 presented at the American Society for Testing and Materials, Los Angeles, California, October 1-5, 1962
(22 references, 22 pages, 20 figures, 2 tables)

A general hypothesis that describes the cumulative effect of plastic deformations on the low-cycle fatigue behavior of metals is presented and verified with results of a variety of tests on steel specimens. Limited correlations with existing test data from other low-cycle fatigue tests on aluminum alloy specimens indicate that it may be possible also to extend this hypothesis to metals other than steel.

49324 TUNED Q ANALYSIS OF QUENCH AND PRECIPITATION HARDENING 4330M AND 17-7PH STEELS. I. G. Hendrickson, The Boeing Company, Seattle, Washington. Paper No. 60 presented at the American Society for Testing and Materials Meeting, Los Angeles, California, October 1-5, 1962
(10 pages, 5 figures, 1 table)

Quench-temper and precipitation hardening processes of 4330M and 17-7PH steels are analyzed as a function of mechanical Q. A tuned Q technique, using the free decay of the unrestrained torsional mode of vibration, is employed in the Q measurements of the test specimens. The tuned Q measurements of the test specimens have proved very sensitive in reflecting both the strain-relieving process of tempering and the strain-related processes of precipitation hardening. It is believed that the changes in Q observed in following these heat-treatment processes are dependent on the degree of lattice distortion or internal strain of the materials. Also, the tuned Q measurements are shown to be a means of analyzing the relative stability of materials as a function of stress and time.

49325 See Coatings.

49326 THE EFFECT OF DECARBURIZATION ON THE FRACTURE TOUGHNESS OF AN ULTRAHIGH-STRENGTH SHEET STEEL. J. P. Sheehan and R. D. Manning, Armour Research Foundation, Chicago, Illinois and U. S. Steel Corporation, Monroeville, Pennsylvania. Paper No. 62 presented at the American Society for Testing and Materials Meeting, Los Angeles, California, October 1-5, 1962
(5 references, 10 pages, 6 figures, 6 tables)

The present work was undertaken to determine by laboratory tests how the fracture toughness of an alloy steel is affected by decarburization. Air-steel X200 was selected for this investigation as a typical air-hardening alloy steel. Three depths of decarburization, four carbon contents, and two tempering temperatures were included in an effort to develop equivalent strengths by several means and thus obtain a cross check on the decarburization effect.

49472 See High-Strength Alloys.

49475 PROCESSING OF SUPERALLOY MULTIFILAMENT YARN. J. A. Rizzardi, Hoskins Manufacturing Company, Detroit, Michigan. Paper presented at the Symposium on Fibrous Materials, Dayton, Ohio, October 16-17, 1962
(2 references, 15 pages, 8 figures, 1 table)

Eight superalloys of A-286, Elgiloy, Hastelloy B, M-252, Rene 41, Udimet 500, Udimet 700 and Waspaloy were processed to ultra fine fibers of .001 inch diameter or less and their room temperature physical properties evaluated. All alloys except A-286 had ultimate strengths in the range of 160,000 to 200,000 psi as solution heat treated. Alloy A-286 had a tensile strength of 100,000 psi.

Multifilament yarns composed of seven (7), nineteen (19) and thirty-seven (37) filaments of Elgiloy and Rene 41 were sheathed with a Chromel-C alloy ribbon and processed to .0027 inch diameter. Tensile strengths were determined for the sheathed yarns at 1600 F, 1800 F, and 2000 F in air and argon. The oxidation resistant Chromel-C considerably improved the 1800 F and 2000 F tensile strength of the Rene 41 alloy, but the effect on Elgiloy was slight.

49497 MACHINING OF REFRACTORY MATERIALS. N. Zlatin, M. Field, and J. Gould, Metcut Research Associates, Inc., Cincinnati, Ohio. ASD TR 7-532a(VIII), November 1962, Phase II Technical Engineering Report, Contract No. AF 33 (600)-42349
(76 pages, 53 figures)

An evaluation of a Tornetic drilling unit and tapping unit is in progress. The torque and speed characteristics of these units have been determined. Comparative drilling tests using the Tornetic drilling unit and a constant feed and speed drill press have been made on 4340 steel quenched and tempered to 52 R_c, B-120VCA titanium solution treated and aged to 400 BHN and Rene 41 solution treated and aged to 370 BHN. Conventional-machining studies were performed on B-120VCA titanium in the solution treated condition (285 BHN), and the aged condition (400 BHN). The investigation consisted of turning, face-milling, end-milling, drilling, reaming, tapping, and grinding tests.

49533 1962 SAE PANEL SESSION ON MANUFACTURE OF SOLID PROPELLANT ROCKET MOTOR CASES (METAL). W. C. Hitt, Automation Industries, Boulder, Colorado. Paper presented at the SAE National Aeronautic and Space Engineering Meeting, Los Angeles, California, October 8-12, 1962
(1 page)

Nondestructive Testing

Several nondestructive test methods are used in the manufacture of solid rocket metal motor cases. These include: thickness measurements, magnetic particle, X-ray inspection, and ultrasonic inspection. Explanations covering these methods are given.

Stainless Steels

49287 See Molybdenum.

49319 METAL FORMING WITH PULSED MAGNETIC FIELD. D. F. Browder, General Dynamics Corporation, General Atomic. GA-3529, October 12, 1962
(1 reference, 17 pages, 17 figures)

This report discusses some of the unique characteristics of the magnetic-pulse metal-forming process, gives some examples of its application to date, and points out in a general way some of the aspects of the design of magnetic-pulse-forming equipment.

49324 See Engineering Steels.

49458 THE PRODUCTION AND PROCESSING OF TYPE 440 STAINLESS STEEL WIRE. B. H. Beverly, Jr. Wire & Wire Products, v. 37, no. 10, October 1962, p. 1422-1425 and 1498-1500
(7 pages, 13 figures)

This paper presents a general outline of the Stainless Steel alloy type 440C with emphasis on the processing phases of wire production. In Section I the broad picture of the Stainless Steels is revealed through examples of alloys from the three basic stainless classes. Section II shows how the Type 440 group (440 A, B, and C) developed from the basic Type 420 analysis. Section III lists the application and usage of the Type 440 group. Section IV deals with the mechanical properties and basic metallurgical characteristics of the Class I alloys in general, and with Type 440 C in particular. Structures, heat treatments, and corrosion resistance are discussed. Section V is a chronological sketch of the difficulties and answers found to wire processing problems with Type 440 C. The heat treating, pickling, and drawing practices that are used today are presented.

49515 See Coatings.

Iron Base

49445 A MODEL FOR YIELDING WITH SPECIAL REFERENCE TO THE YIELD-POINT PHENOMENA OF IRON AND RELATED BCC METALS. G. T. Hahn. Reprinted from Acta Metallurgica, v. 10, no. 8, August 1962, p. 727-738
(54 references, 12 pages, 12 figures, 3 tables)

A model for yielding based on dislocation multiplication and velocity characteristics specific to iron and related body-centered-cubic metals is derived on the premise that dislocations anchored by segregates or precipitates remain locked. The abrupt yield drop is a consequence of rapid multiplication and the stress dependence of dislocation velocity. The model describes continuous and discontinuous yielding, the Luders' band, the delay-time phenomenon, and offers a unified treatment of these phenomena qualitatively in accord with experiments. Macroscopic strain-rate sensitivity and the Luders' band-front velocity are shown to be related to dislocation-velocity characteristics. The model also accounts for yield-point anomalies associated with strain aging. Although the possibility of unlocking is not excluded, these considerations imply that the importance of unlocking may have been overstated.

49469 18% NICKEL MARAGING STEEL. The International Nickel Company, Inc., New York, New York. Interim Data Sheet TL 10, October 17, 1962
(7 pages, 3 figures, 6 tables)

Information is presented on the composition, heat treatment, hot working, dimensional stability, hardness and tensile properties, effect of cold reduction, welding, and stress-corrsoion, cracking resistance of 18 per cent nickel maraging steel.

LIGHT METALS

49319 See Stainless Steels.

49354 EFFECTS OF FUEL CONTAMINATION ON CORROSION OF AIRCRAFT FUEL SYSTEMS. W. J. Digman, Douglas Aircraft Company, Society of Automotive Engineers, Inc., New York, New York. Paper No. 575A presented at the National Aerospace Engineering & Manufacturing Meeting, Los Angeles, California, October 8-12, 1962
(12 references, 6 pages, 7 figures)

Turbine fuel contaminants such as surface active agents, saline water, and iron rust provide an ideal environment for extensive growth of microorganisms in fuel, resulting in a serious corrosion problem to aircraft fuel systems. Contamination sources, means of entry into the aircraft, and effects on the fuel system are discussed. Recently developed detection methods and an improved quality-control procedure which alleviate the problem are described.

49419 THE EFFECT OF SIZE AND STRESS HISTORY ON FATIGUE CRACK INITIATION AND PROPAGATION. W. Weibull, Bockamollan, Brosarps Station, Sweden. ASD TDR 62-785, August, 1962, Contract No. AF 61(052)-522
(8 references, 23 pages, 16 figures, 2 tables)

The first part of the investigation deals with the effect of size and preloading on the duration N_i of the crack initiation period. Geometrically similar sheet specimens of two different aluminum alloys were subjected to various load cycles.

The second part of the investigation deals with the propagation period. Equations relating crack length to number of cycles are derived for two alternatives: constant stress cycle and constant load cycle applied to a sheet specimen. The formulas are verified by tests including various combinations of material, size, and stress amplitude.

Beryllium

49459 RECENT ADVANCES IN THE FABRICATION OF BERYLLIUM COPPER ROD AND WIRE. K. G. Wikle. Wire and Wire Products, v. 37, no. 10, October 1962, p. 1447-1451 & 1507
(6 pages, 15 figures, 7 tables)

The purpose of this paper is to review the beryllium-copper industry and tie its significance into the manufacture and application of beryllium-copper rod and wire.

49498 DEVELOPING TECHNOLOGY TO FORGE UNCLAD BERYLLIUM. M. B. Hornak and R. G. O'Rourke, The Brush Beryllium Company, Cleveland, Ohio. ASD, Phase I - Final Report, TR 280-237, September 10, 1962, Contract No. AF 33(657)-8507
(10 references, 45 pages, 19 figures, 9 tables)

A review of a state-of-the-art survey is presented in addition to results from a limited amount of experimental forging of unclad beryllium billets employing upset-forging methods. Also, an engineering plan for Phases II and III of this project is presented in moderate detail.

Titanium

49286 THE STATUS AND PROPERTIES OF TITANIUM ALLOYS FOR THICK PLATE. G. E. Faulkner, W. J. Lewis, and D. C. Martin. Battelle Memorial Institute, Columbus, Ohio. Navy Bureau of Ships, Draft Report, October 15, 1962 (11 references, 58 pages, 10 figures, 11 tables)

DMIC was asked to support the Bureau of Ships Titanium Development Plan for Advanced Deep-Diving Submersibles by providing pertinent data compilations and preparing appropriate state-to-the-art reviews. This draft report on titanium for thick plate is DMIC's first formal response to that request. This draft has four purposes:

(1) it describes the metallurgical characteristics of titanium alloys, and then goes on to relate titanium's character to thick-plate applications,
(2) it summarizes current knowledge about the mechanical properties of titanium alloys in thick-plate form,
(3) it discusses the weldability of titanium alloys in terms of the thick-plate application, and
(4) it outlines briefly the status of present knowledge about fabricating thick plates of titanium alloys.

49349 LOW CYCLE FATIGUE OF Ti-6Al-4V AT -423°F. R. R. Hilsen, C. S. Yen, and B. V. Whiteson, Douglas Aircraft Company, Inc., Santa Monica, California. Engineering Paper No. 48, presented at the American Society for Testing and Materials Meeting, Los Angeles, California, October 1-5, 1962 (10 references, 22 pages, 10 figures, 1 table)

To determine the effect of various factors on low-cycle-fatigue phenomena in connection with space-vehicle design, axial-tension-fatigue tests up to 2000 cycles were conducted on titanium alloy, Ti-6Al-4V, at -423 F.

Two types of fractures were observed, depending on the fatigue life. A transition in the fracture appearance occurs between 700 and 2000 cycles where the fracture changes from a cup and cone to a more typical surface-initiated fatigue fracture.

Possible mechanisms are discussed.

49404 MECHANICAL PROPERTIES OF AN ALPHA TITANIUM ALLOY AT CRYOGENIC TEMPERATURES. F. R. Schwartzberg and R. D. Keys, The Martin Company, Denver, Colorado. Paper presented at the Annual ASTM Meeting, New York, New York, June 23-29, 1962 (9 references, 16 pages, 6 figures, 3 tables)

This report contains the results of an evaluation of the effects of interstitial content, i.e. carbon, oxygen, and nitrogen, on the notched- and unnotched-tensile properties of the all-alpha titanium alloy Ti-5Al-2.5Sn at temperatures from 70 to -423 F.

Test results show that ductility and notch sensitivity are drastically affected by variations in interstitial content. By controlling interstitial additions to sufficiently low levels, excellent notch toughness and ductility were obtained at temperatures as low as -423 F.

49497 See Engineering Steels.

49515 See Coatings.

49516 TITANIUM IN 1975. R. I. Jaffee, Battelle Memorial Institute, Columbus, Ohio. May 9, 1962, Rough Draft.
(51 pages, 13 figures)

Titanium has come to be regarded as the classic example of an accelerated development of a defense-oriented material through government requirements and support. It is apparent that the research and development phase in titanium is largely over, and that the metal has entered a growth period into a widening spectrum of applications. Hence, it is timely to consider what titanium may look like at maturity.

At the annual meeting in New York last fall, the Titanium Symposium was devoted to the future of titanium, "Titanium in 1975". The early 1960's can be taken as the midpoint of titanium's growth curve, and should afford a good basis from which to project an image of what the mature titanium industry will look like.

Magnesium

49426 STUDIES OF MAGNESIUM ALLOYS FOR USE AT MODERATE TEMPERATURES. R. L. Crosby and K. A. Fowler, U. S. Department of the Interior, Bureau of Mines, Washington, D. C. RI 6078, 1962
(22 references, 28 pages, 16 figures, 5 tables)

From studies of wrought magnesium alloys containing rare-earth elements, data are presented on the mechanical properties of the alloys at room temperature and at temperatures of 100, 200, and 300 C. Results of studies of the solid solubility of cerium and zirconium in magnesium, as determined by electrical-resistance measurements, are also discussed and are compared with those of other investigators.

NONMETALLICS

49400 MATERIALS - LAMINATES - PLASTIC - COTTON BASE PHENOLIC (WESTINGHOUSE CORP. MICARTA). COTTON BASE EPOXY (BLOOMINGDALE RUBBER CO. LP-138), NYLON BASE EPOXY (GENERAL DYNAMICS/CONVAIR), AND DACRON BASE EPOXY (GENERAL DYNAMICS/CONVAIR), CLOSED SYSTEM GAS PRESSURE AT 300 & 325 F°. H. H. Hunt, General Dynamics Corporation, Convair, San Diego, California. Report No. 8926-031, April 11, 1962
(13 pages, 3 figures, 5 tables)

The comparative gas pressures generated at 300 and 350 F in the presence of bonding pressures used to assemble plastic laminates into built-up adhesive-bonded structures were measured in a specially built bomb held between the heated platen of a bonding press. Phenol formaldehyde resins were found to exert high comparative gas pressures at 350 F, but not at 300 F. Epoxy resins exerted only negligible pressures at either temperature. Cotton and purified-cellulose fillers exerted high gas pressures. Nylon exerted a low gas pressure, and the dacron exerted only an appreciable gas pressure. Material and laminating detail relative to the non-commercial nylon-base and dacron-base epoxy-resin-bonded laminates are given.

49478 DEVELOPMENT OF QUARTZ FIBER PARACHUTE MATERIALS. C. C. Chu, D. H. Powers, Jr., L. Barish, and E. R. Kaswell, Fabric Research Laboratories, Inc., Dedham, Massachusetts. Paper presented at the Symposium on Fibrous Materials, Dayton, Ohio, October 16-17, 1962
(7 pages, 2 figures)

This research project was initiated to investigate the feasibility of utilizing quartz fibers for the fabrication of various parachute components.

Potentially, individual quartz fibers when handled with extreme care, have tenacities up to 15 grams per denier at room temperature. As much as 50 per cent of this tenacity remains at 1800 F. Quartz fibers are even worse than fiberglass in that they are extremely brittle, sensitive to scratching, and have virtually no abrasion resistance when unprotected. Therefore, the initial portion of the research effort was directed to the development of a high temperature finish which would facilitate the processing of the fibers at room temperature as well as to afford protection at elevated temperatures.

49531 EMISSIVITY CONTROL OF HIGH TEMPERATURE CERAMICS. W. H. Wheeler, The Martin Company, Baltimore, Maryland. Paper presented at the American Ceramic Society, October 5, 1962
(6 references, 4 pages, 7 figures)

There is a requirement for providing high emissivity to ceramic components exposed to high heat-pulse loadings (50-200 Btu/ft^2-sec). Most ceramic materials are characterized by low values of emissivity. Surface coatings, using high-emissivity materials--such as nickel, chromium, or cobalt oxides, silicon carbide, or molybdenum disilicide--are best suited for this application. Coatings may be applied by chemical bonding, sintering, or flame-spraying. For use as antenna windows, the high emissivity coatings must further be capable of transmitting a dielectric signal without distortion.

49548 RESEARCH ON ELEVATED TEMPERATURE RESISTANT CERAMIC STRUCTURAL ADHESIVES. R. J. Forlano, D. M. Krumwiede, J. F. Benzel, H. R. Thornton, H. G. Lefort, and D. G. Bennett, University of Illinois, Urbana, Illinois. WADC TR 55-491, Part VI, June 1962, Final Report, Contract No. AF 33(616)-6192 (7 references, 72 pages, 25 figures, 11 tables)

Ceramic or inorganic type adhesives, relatively resistant to thermal and mechanical shock and capable of sustained strengths at temperatures up to 1500 F and now targeting 2000 F, have been investigated. Several alterations of the basic glassy phase were studied to attain optimum adhesion properties. Included were the incorporation of metal fillers, recrystallizable materials and other special techniques to the basic glassy phase.

The basic physical properties, thermal expansion, residual stress and tensile strength, were correlated with bond strength. Mean tensile strength values of 5000 psi at room temperature and 3000 psi at 800 F can be expected of ceramic adhesives.

Addition of selected bonding oxides to a barium borosilicate glass to develop covalent-like bonds resulted in increased tensile shear strengths at temperatures above 1000 F. The incorporation of metal fillers improved the physical properties of the basic ceramic adhesives. Recrystallized-type adhesives would not develop strong cohesive bonds unless a glassy phase was present.

The formation of phosphate bonds was considered for use as a low-temperature-maturing inorganic adhesive.

Carbon, Graphite

49285 HIGH TEMPERATURE MATERIALS DEVELOPMENT. Raytheon Company, Waltham, Massachusetts. Final Report, Bureau of Naval Weapons, S-460, Contract No. NOw 61-0155-c
(4 references, 11 pages, 2 figures, 1 table)

First and second-stage PYROGRAPHITE nozzle inserts, which consisted of a PYROGRAPHITE coating, 150 mils thick, on ATJ graphite, were fabricated. To meet the requirement two furnace runs, using a single mandrel, were conducted. These produced apparently sound pieces which were not machined.

49357 UNCOOLED ROCKET NOZZLES FOR ULTRA-HIGH TEMPERATURE PROPELLANTS. G. Kraus, Curtiss-Wright Corporation, Society of Automotive Engineers, Inc, New York, New York. Paper No. 595J presented at the National Aerospace Engineering & Manufacturing Meeting, Los Angeles, California, October 8-12, 1962
(4 pages, 10 figures, 1 table)

The Curtiss-Wright pyrolytic graphite nozzle discussed in this paper extends the capability of uncooled lightweight nozzles to future ultrahigh-temperature propellants by utilizing a novel application of pyrolytic graphite. The pyrolytic graphite is used as a heat sink rather than an insulator by having it oriented to conduct heat away from the hot surface to the interior of the nozzle. The results of small-scale tests using propellants with flame temperatures up to 6550 F are presented. Some mention of full-scale nozzle design is also made.

49499 RESEARCH AND DEVELOPMENT ON ADVANCED GRAPHITE MATERIALS VOLUME X. THERMAL REACTIVITY OF AROMATIC HYDROCARBONS. I. C. Lewis and T. Edstrom, Union Carbide Corporation, National Carbon Company, Parma, Ohio. WADD TR 61-72, v. X, August 1962, Contract No. AF 33(616)-6915
(21 references, 41 pages, 4 figures, 5 tables)

A general survey is given of the thermal reactivity of aromatic hydrocarbons to provide information basic to the understanding of the conversion of organic materials to carbon. Differential-thermal analysis was employed on 84 aromatic hydrocarbons to delineate the thermal sequences during pyrolysis to 750 C. Absorption spectra, electron-spin resonance, chromatography, and molecular-weight determinations have been used to determine the mechanisms and structural changes which occur.

49511 RESEARCH AND DEVELOPMENT ON ADVANCED GRAPHITE MATERIALS VOLUME VIII. L. S. Singer and G. Wagoner, Union Carbide Corporation, National Carbon Company, Parma, Ohio. WADD TR 61-72, v. VIII, June 1962, Contract No. AF 33(616)-6915
(22 references, 13 pages, 6 figures)

The electron-spin resonance of polycrystalline graphite is shown to be due to charge carriers, as for single crystals. For lampblack-base

49511 (Continued)

graphite, the variation in g-value with temperature agrees approximately with that for single-crystal graphite if it is assumed that the spins effectively average out the anistropic interactions by rapid intercrystallite diffusion. The magnitude and temperature dependence of the spin susceptibility are found to be in excellent agreement with McClure's theoretical predictions for the charge carriers in perfect graphite. Complications of measuring these materials are discussed, including effects of skin depth and microwave heating and the dependence upon crystallite size and sample purity. It is found that two types of impurities can affect the resonance; those which become ionized and shift the Fermi level, and large un-ionized atoms which do not shift the Fermi level but act as efficient scattering centers for shortening the spin-lattice relaxation time.

Special Refractories

49235 SELECTION AND FABRICATION OF CERAMICS AND INTERMETALLICS. J. D. Latva, Metal Progress, v. 82, no. 4, October 1962, p. 139-144, 180 & 186 (8 pages)

The nature of brittle fracture in refractory ceramics is discussed. Physical, thermal, and mechanical properties of borides, carbides, and nitrides are presented.

49289 See Refractory Metals.

49353 See Refractory Metals.

Ceramic Oxide

49436 ANISOTROPY AND STRENGTH OF CERAMIC BODIES. W. R. Buessem and H. A. McKinstry, The Pennsylvania State University, University Park, Pennsylvania. USN, Progress Report No. 3, July 30, 1962, Contract No. NOnr-656(27)
(3 references, 23 pages, 2 tables)

Previous work on aluminum titanate revealed that its directional-thermal-expansion coefficients α_a, α_b and α_c are highly anisotropic. Our work on the thermal expansion of this structure and other ceramic bodies is to confirm the previous work and to determine a standard set of values for the anisotropy behavior of the thermal expansion on which other arguments may be based.

49477 HIGH STRENGTH GLASS FIBER TAPES AND WEBBINGS FOR HIGH TEMPERATURE PRESSURE PACKED DECELERATOR APPLICATIONS. E. S. Cobb, Jr., Owens-Corning Fiberglas Corporation, Paper presented at the Symposium on Fibrous Materials, Dayton, Ohio. October 16-17, 1962
(10 pages, 5 figures)

A basic method of fabricating glass fiber textile structures that should operate satisfactorily in pressure packed decelerators which must undergo thermal exposure to 500 F for a period of 5 hours has been developed.

49513 THE CORROSION OF REFRACTORIES. W. A. Miller and C. B. Clark, Harbison-Carborundum Corporation, Report presented at American Ceramic Society Fall Meeting of Refractories, Bedford Springs, Pennsylvania. October 4-6, 1962
(26 pages, 19 figures)

The results of numerous corrosion tests are reviewed with regard to current theories on the mechanism of corrosion. Rates of corrosion of various refractories by commercial glasses are given. The effects of both physical and chemical factors on corrosion rates are discussed.

REFRACTORY METALS

49289 DEVELOPMENT OF 2400° F FORGING DIE SYSTEM. H. Nudelman, A. H. Murphy, T. Watmough, and P. R. Gouwens, Armour Research Foundation of Illinois Institute of Technology, Chicago, Illinois. ASD TR 7-886, (VI), Interim Technical Progress Report, ASD, October 1962, Contract No. AF 33(600)-42861
(39 pages, 23 figures, 7 tables)

It has been demonstrated that a high-temperature (1500 F) die does permit a reduction from five to one in the number of die sequences required, provided that a trapped-die technique is also used. The shape of the preform was progressively altered until die filling was obtained in a single step forging-extrusion operation. The preform shapes were bars and round-cornered square billets, having dimensions suitable to the final forging. Ceramic forging dies for use at 2400 F were tested as simple punches. Titanium diboride, KT silicon carbide, and Refrax successfully withstood the test, but were sensitive to lubricant characteristics.

49290 See High-Strength Alloys.

49353 PROBLEMS IN THE OXIDATION PROTECTION OF REFRACTORY METALS IN AEROSPACE APPLICATIONS. R. A. Perkins, L. A. Riedinger, and S. Sokolsky, Lockheed Missiles and Space Company, Sunnyvale California. Paper presented at Transactions of the 7th Symposium on Ballistic Missile and Space Technology, USAF Academy, Colorado, August 13-16, 1962
(12 references, 22 pages, 11 figures)

This paper presents an evaluation of protective coatings for refractory metals and critical problem areas in the light of requirements for radiation-equilibrium-cooled structures. Environmental conditions of temperature, pressure, flow, and time for hypersonic re-entry vehicles are described. The effect of atmospheric pressure and flow on the performance of the most promising coating systems is discussed. Data are presented to show that rapid deterioration of silicide-base coatings can occur under re-entry environmental conditions. Current oxidation-test data can be misleading and potential uses of coated structures should be re-assessed. Improved coatings must be developed for use in low-pressure environments.

49437 See Columbium.

49495 CREEP OF POLYCRYSTALLINE METALS. Department of the Navy, Office of Naval Research, London, England. European Scientific Notes No. 16-6, June 25, 1962, p. 124-125
(2 pages)

Surface grains offer less resistance to creep than intergrains and a very thin coating of a foreign metal will notably increase the creep resistance. The permanent flow is less with large grains and larger stresses than with smaller grains. This is attributed to the irregularities produced by slip within the grains which impede their relative motion.

49495 (Continued)

Results include the effects of grain size and coatings on the several parameters in the expression to describe the creep process.

49522 SPACE CHAMBER EMITTANCE MEASUREMENTS. C. P. Butler and R. J. Jenkins, U. S. Naval Radiological Defense Laboratory, San Francisco, California. Preprint of paper, v. I, presented by ASD, National Bureau of Standards & NASA, Dayton, Ohio, September 5-7, 1962
(8 pages, 2 figures)

A method for evaluating the total effective emittance of an evacuated space chamber, without recourse to optical techniques, is described. The chamber emittance can be evaluated from the temperature decay and heat center of a hollow-walled chamber cooled by liquid nitrogen. Shutters admit a beam of radiant energy from an image furnace to heat the disc. Experimental results are given for a black space chamber in which materials may be tested from 200 C to -140 C.

Columbium

49278 STATUS REPORT NO. 2 ON DEPARTMENT OF DEFENSE REFRACTORY METALS SHEET-ROLLING PROGRAM. H. R. Ogden, Battelle Memorial Institute, Columbus, Ohio. DMIC Report 176, October 15, 1962
(2 references, 36 pages, 15 figures, 2 tables)

During this period emphasis in the many programs involved has been on developing optimum sheet-fabrication procedures.

The columbium program is nearing completion of laboratory-rolling studies, and a single composition for larger scale rolling studies will be selected in the near future. In the molybdenum program, it has been shown that true hot forging of billets to sheet bar results in higher recrystallization temperatures of TZM and Mo-0.5Ti sheet than are obtained when normal forging temperatures are used. The tantalum program is in the early stages of ingot production and primary breakdown fabrication of the Ta-30Cb-7.5V alloy.

Three methods of fabricating tungsten sheet are being investigated: rolling of powder-metallurgy billets, fabrication of arc-melted ingots, and floturning of cylindrical blanks. Properties obtained on both powder-metallurgy and arc-melted tungsten sheet compare very favorably.

Evaluation of the formability of molybdenum-alloy sheet has been delayed until sheet is available from the production program.

49363 REFRACTORY METALS STRUCTURAL DEVELOPMENT PROGRAM VOLUME IV: STRUCTURAL COMPONENT DESIGN AND FABRICATION. C. W. Neff and R. G. Frank, McDonnell Aircraft Corporation, St. Louis, Missouri, and General Electric Company, Evandale, Ohio. ASD TR 61-392, Volume IV, August 1962, Contract No. AF 33(616)-6578
(109 pages, 60 figures, 10 tables)

Information is given on the design and fabrication of a representative load-carrying structural component capable of efficient operation in the temperature range of 1800 F to 2500 F. The final component (fin-rudder assembly), basically was fabricated from F-48 columbium alloy and coated with General Electric LB-2 (Al-Cr-Si) slurry coating for oxidation protection. Major problem areas such as material processing, joining, and protection are discussed.

49437 COLUMBIUM-HAFNIUM BINARY ALLOYS FOR ELEVATED-TEMPERATURE SERVICE. H. R. Babitzke, G. Asai, and H. Kato, U. S. Department of the Interior, Bureau of Mines, Washington, D. C. RI 6101, 1962
(9 references, 17 pages, 9 figures, 6 tables)

The purpose of this investigation was to evaluate the potential of columbium-hafnium alloys as structural materials for use at elevated temperatures. The work described in this report was conducted to determine the properties of columbium-hafnium alloys and to select the more promising ones for further improvement. Properties determined in this report were machinability, hardness, workability, tensile strength, and oxidation resistance. Ten ingots, ranging from 100 per cent columbium to 70 atomic per cent hafnium, were prepared and subjected to tests.

Molybdenum

49274 See Applications.

49278 See Columbium.

49287 A STUDY OF FORGING VARIABLES. H. J. Henning, J. W. Spretnak, A. M. Sabroff, and F. W. Boulger, Battelle Memorial Institute, Columbus, Ohio. ASD TR 61-7-876, Interim Technical Engineering Report No. 3, ASD, May, 1962, Contract No. AF 33(600)-42963
(48 references, 192 pages, 111 figures, 29 tables)

The primary objective of this study is to prepare an engineering report in the form of a manual on "The Fundamentals of Forging". The material for this report comprises data obtained from literature, from industrial sources, and from a laboratory-scale experimental program designed to study significant forging characteristics of several typical alloys. This Interim Report presents preliminary drafts of sections that will appear in the final report. These are concerned with certain aspects of metal-flow theory and forging practices. Emphasis this quarter was directed to preparing sections on forging materials. In the experimental studies, forgeability and forging-pressure data were obtained on the Mo-0.5Ti-0.08Zr alloy forged at temperatures as low as 1500 F with reductions up to 95 per cent.

49438 REFRACTORY METAL CONSTITUTION DIAGRAMS. E. J. Rapperport and M. F. Smith, Nuclear Metals, Inc., Concord, Massachusetts; J. Wulff, J. Brophy, N. J. Grant, and B. C. Giessen, Massachusetts Institute of Technology, Cambridge, Massachusetts; A. Taylor and N. Doyle, Westinghouse Research Laboratories. WADD TR 60-132, Part II, Final Report, September, 1962, Contract No. AF 33(616)-7157
(10 references, 185 pages, numerous figures, numerous tables)

Data on six binary-constitution diagrams and two ternary-constitution diagrams of some of the refractory metals are presented. The binary diagrams include Mo-Os, Ta-Ir, Ta-Rh, Ta-Zr, W-Ir, and W-Rh; the ternaries are Mo-Hf-Re and Ta-W-Zr.

Care was taken to obtain reliable diagrams. In particular the purity of the constituents (99.9 per cent plus) was protected at all times, and the temperatures were measured to an accuracy of ±20 C.

49439 COMPARISON OF HIGH ENERGY RATE (DYNAPAK) AND CONVENTIONAL EXTRUSION OF REFRACTORY METALS. D. G. Rabenold, Westinghouse Electric Corporation, Blairsville, Pennsylvania. ASD TDR 62-506, September, 1962, Contract No. AF 33(616)-7842
(6 references, 90 pages, 45 figures, 21 tables)

A comparison was made of the surface quality, dimensions, chemistry, hardness, tensile properties, and recrystallization behavior of extrusions produced on a Model 1810 Dynapak high-velocity machine and on a 700-ton Loewy high-speed extrusion press. Three temperatures were established which represented hot work, cold work, and a combination of hot and cold work, by making preliminary extrusions on the Dynapak

49439 (Continued)

machine. Arc-cast billets, with a nominal diameter of three inches, of two refractory alloys, a Mo-25W-0.1Zr alloy and a W-0.6Cb alloy, were then extruded at a constant 4:1 reduction ratio from the same three temperatures on both machines.

Rhenium

49438 See Molybdenum.

Tantalum

49278 See Columbium.

49362 ULTRA-SHORT-TIME CREEP RUPTURE. J. P. Knight, W. A. Cosby, and H. W. Leavenworth, American Machine & Foundry Company, Alexandria, Virginia. WADC TR 59-762, Part IV, August 1962, Contract No. AF 33(616)-7632 (203 pages, 85 figures, 52 tables)

This program involved the design and fabrication of ultra-short-time creep-test equipment and utilization of the equipment for determining the short time mechanical properties of a structural refractory-metal-sheet alloy at elevated temperatures. Tensile test specimens of National Research Corporation Ta-10 per cent alloy were strained at temperatures of 2000 F, 2500 F, 2750 F, and 3000 F in an argon atmosphere and in a vacuum (3000 F only). Heating of test specimens to maximum temperature was accomplished in approximately 60 milliseconds. Tensile loading of test specimens at each temperature was accomplished prior to attaining test temperature and 1/2 second, 2.0 seconds, and 5.0 seconds after attaining test temperature. A description of test apparatus, test procedures, and complete test data are given in this report.

49438 See Molybdenum.

Tungsten

49278 See Columbium.

49438 See Molybdenum.

49439 See Molybdenum.

49514 ULTRASONIC INSPECTION OF TUNGSTEN ROUND ROBIN BILLETS, PHASE I. S. D. Hart and L. C. Cardinal, U. S. Naval Research Laboratory, Washington, D. C. Technical Memo No. 214, October 29, 1962
(9 pages, 9 figures)

The tests conducted were primarily to determine the following: (1) best transducer frequency, (2) method of waterproof wrapping of uninfiltrated billets for immersed inspection, (3) velocity of sound measurements to detect density variations, and (4) detection of internal defects by both longitudinal and shear waves.

Platinum Group

49457 THERMAL CONDUCTIVITIES AND ELECTRICAL RESISTIVITIES OF THE PLATINUM METALS.
R. W. Powell and M. J. Woodman. Platinum Metals Review , v. 6, no. 4, October 1962, p. 138-143
(24 references, 6 pages, 3 figures, 2 tables)

New values are presented and discussed for the thermal conductivities and electrical resitivities of ruthenium, osmium, rhodium, iridium, palladium and platinum over the approximate temperature range 80 to 500 K.

MISCELLANEOUS

49277 ESTABLISHMENT OF THE APPROACH TO, AND DEVELOPMENT OF, INTERIM DESIGN CRITERIA FOR SONIC FATIGUE. G. E. Fitch, T. R. Dutko, L. M. Brennan, A. G. Tipton, P. M. Belcher, P. Wang, and P. A. Clawson, North American Aviation, Inc., Los Angeles, California. ASD TDR 62-26, June 1962, Contract No. AF 33(616)-7694
(46 references, 154 pages, 65 figures, 25 tables)

A literature survey provided the background from which an approach was selected for development of design criteria for sonic fatigue. The approach selected was accelerated, discrete-frequency life-testing, the results of which are interpreted using a sine-random equivalence analysis. This approach offers the best compromise between economy, accuracy, and lead time to cover structural-design problems for advanced design, design development, and prooftesting of completed vehicle structure. Methods were extracted from the literature with which to predict the acoustic environment and determine the duration of various environments from mission analysis. Fatigue data and an examination of cumulative damage are presented in support of the sine-random equivalence technique. This method takes advantage of the extensive fatigue S-N data available in the industry. Examples of the application of the analytical-empirical techniques are presented.

49328 OBTAINING MATERIALS BEHAVIOR INFORMATION ON NEW ABLATIVE HEAT SHIELD MATERIALS. L. S. Lazar and T. K. Pugmire. Paper No. 65 presented at the American Society for Testing Materials Meeting, Los Angeles, California, October 15, 1962
(8 references, 23 pages, 9 figures)

In this paper the authors trace the current industrial materials evaluation efforts on ablative-shield materials form inception, through development and design, to utilization. In many cases suggested changes in procedures are recommended. These changes, which must be based on furthering experimental technology, should result in efficient materials programs with higher success potential. Discussion is also presented on the possibility of standardizing evaluation efforts in this field.

49335 INFRARED NONDESTRUCTIVE TESTING OF GLASS FILAMENT WOUND ROCKET MOTOR CASES. F. E. Alzofon, L. E. Florant, R. K. Ronald, M. J. Vann, and J. E. Fitzgerald, Lockheed Missiles and Space Company, Sunnyvale, California. Paper No. 76 presented at the American Society for Testing and Materials Meeting, Los Angeles, California, October 1-5, 1962
(13 pages, 9 figures)

A description of experimental and theoretical studies leading to the demonstration of the feasibility of flaw detection in glass-filament-wound rocket-motor cases, utilizing infrared scanning, is presented. The importance of selecting the best method of heating the specimen, in order to optimize the information derived from observation is emphasized. Sources of error are reviewed. The apparatus, measurement techniques, and experimental results are described.

49351 TEST METHODS FOR FILAMENT WOUND SPECIMENS. S. Yurenka, Douglas Aircraft Company, Inc., Santa Monica, California. Paper No. 1473 presented at the American Society for Testing and Materials Meeting, Los Angeles, California, October 1-5, 1962
(4 references, 16 pages, 23 figures, 1 table)

Based largely on work performed under a recently completed Air Force Contract, a systematic investigation of suitable testing methods was performed and is the subject of this paper. The specimens consisted of wound rings, cylinders, and cylindrical pressure vessels, and the tests included unidirectional and biaxial tension, compression, shear, and bending. The accuracy and usefulness of eight different tests are assessed and representative experimental data are presented. The specimens and testing jigs are illustrated and described. It is expected that some of the test methods will eventually become incorporated into standard ASTM and military specifications.

49352 THE PREDICTION OF HEAT TRANSFER AND ABLATION IN THE AFT-CLOSURE OF A SOLID PROPELLANT ROCKET MOTOR. W. C. Kuby, Jr. and J. L. Richardson, Ford Motor Company, Aeronutronic Division, Newport Beach, California. Paper presented at Transactions of the 7th Symposium on Ballistic Missile and Space Technology, USAF Academy, Colorado, August 13-16, 1962, Contract No. AF 04(611)-7047
(45 references, 40 pages, 10 figures)

A mathematical design model has been developed for the prediction of insulation requirements in the aft-closure of a solid-propellant rocket motor. This model and the associated calculation technique represent only a first approximation to the exact solution of a problem concerned with various complex phenomena. The behavior of ablative-elastomeric-insulation materials in such an application is considered. The choice of the assumptions used to calculate the forced convective and radiative-heat fluxes is based on recent experimental results. A summary is made of the information still to be determined in order that this model can be fully utilized.

49356 JET FUEL CONTAMINATION: WATER, SURFACTANTS, DIRT AND MICROBES. J. D. Rogers, J. A. Krynitsky, and A. V. Churchill, E. I. du Pont de Nemours & Co., Inc., Naval Research Laboratory, & ASD, Society of Automotive Engineers, Inc., New York, New York. Paper No. 583C presented at the National Aerospace Engineering & Manufacturing Meeting, Los Angeles, California, October 8-12, 1962
(22 references, 12 pages, 21 figures, 7 tables)

Fuel contaminants have been pinpointed as the cause of several accidents in military jet aircraft and "incidents" during operation. Free water and dirt, normally filtered out and separated prior to servicing, have been recognized as the principal offenders. Recent studies have shown that the performance of filter-separator equipment can be affected significantly by slight changes in the fuel's chemical constituents. The efficiency of fuel purification can be degraded by certain additives and trace quantities of surfactants. In addition to causing direct damage, the presence of water and dirt creates an environment for growth of microorganisms.

49365 STORABLE LIQUID PROPELLANTS NITROGEN TETROXIDE/AEROZINE 50. Aerojet-General Corporation, Sacramento, California. Report No. LRP 198, Second Edition, June 1962
(numerous pages, numerous figures, numerous tables)

The primary purpose of this publication is to present useful information to project personnel concerned with research, development, and testing of storable propellants and propulsion systems in which these propellants are used.

49439 See Molybdenum.

49503 THE MINIMUM WEIGHT DESIGN OF STRUCTURES OPERATING IN AN AEROSPACE ENVIRONMENT. H. Switzky, Republic Aviation Corporation, Farmingdale, Long Island, New York. ASD TDR 62-763, RAC 442-1(ARD-823-2), October 1962, Contract No. AF(657)-7872
(22 references, 123 pages, 27 figures, 10 tables)

A nondimensional-design technique is developed to obtain the minimum weight of structural components (columns, plates, and beams) subjected to an aerospace environment. Design curves are developed and presented for various structural configurations in terms of the applied loads and geometric and material parameters which can be readily evaluated. The design technique can be employed to obtain, in a relatively simple and rapid manner, preliminary estimates of the structural-design weight as well as a good approximation to the final design. The design procedure for minimum weight is illustrated for a truss-like spar and a wing section which are typical of aerospace structures.

49504 HEAT TRANSFER AND PARTICLE TRAJECTORIES IN SOLID-ROCKET NOZZLES. L. P. Travis, General Tire & Rubber Company, Aerojet General, Sacramento, California. AFBSD TDR 62-165, Technical Note, Report No. 0162-01TN-17, October 19, 1962, Contract No. AF 33(600)-36610
(12 pages, 6 figures)

Particles present in the exhaust products of solid propellants to which aluminum has been added impinge on the walls of the rocket nozzles, transfer heat to the walls, and erode portions of the nozzles.

To analyze the effect of impingement, new techniques have been developed for calculating three-dimensional particle trajectories and for determining the effects of these particles on heat transfer and erosion in a rocket nozzle. Methods are presented for determining approximate particle trajectories in the subsonic portions of the nozzle by use of an analog computer and for obtaining more accurate digital-computer solutions that can be applied to both the subsonic and supersonic portions.

The particle-trajectory studies show that impingement is most severe at the throat region of the nozzle and at the outboard side of the exit cone for multiple-nozzle motors. General equations of motion are presented suggesting nozzle geometries to minimize particle impingement.

49518 CURRENT STATUS AND PROSPECTS OF ION PROPULSION. J. M. Teem and G. R. Brewer, Electro-Optical Systems, Inc., Pasadena, California. Hughes Research Laboratories, Malibu, California, American Rocket Society Paper No. 2650-62
(28 references, 50 pages, 19 figures, 3 tables)

The current status and future prospects of ion propulsion are reviewed. General background information is briefly presented to provide orientation of the non-specialist. The current status of work in ion propulsion is categorized and described in several areas. These include thrustor development, applied research on ion sources, propellant-control-subsystem development, power-conditioning-subsystem development, performance testing, and application studies. Several areas are noted in which important developments can be expected in the near future. These include increased emphasis on life and reliability experimental evaluation, results from early flight tests of prototypes, increasing experience with system interactions and development of prototype systems, and increases in demonstrated over-all performance levels. The importance and character of future work in this field are also discussed.

49523 ERRORS OCCURRING IN THE CALORIMETRIC METHOD OF TOTAL HEMISPHERICAL EMITTANCE MEASUREMENT. K. E. Nelson and J. T. Bevens, Space Technology Laboratories, Inc., Redondo Beach, California. Preprint of paper, v. I, presented by ASD, National Bureau of Standards & NASA, Dayton, Ohio, September 5-7, 1962
(7 references, 21 pages, 6 figures)

There are basic minimal errors which are inherent in the calorimetric method and which are primarily dependent upon the ratio of the sample temperature and the radiation environment. The purpose of this paper is to discuss these minimal errors in quantitative terms and to discuss the other contributions to the total error in more general terms. An analysis of the calorimetric method is developed from the basic heat balance of the sample, the analytic expression for the radiation cooling, and the linear expression for the factors contributing to the total error.

49524 EXPANDABLE STRUCTURES FOR AEROSPACE APPLICATIONS. F. W. Forbes, Directorate of Aeromechanics, ASD, Wright-Patterson Air Force Base, Ohio. American Rocket Society Paper No. 2697-62, presented at 17th Annual Meeting and Space Flight Exposition, Los Angeles, California, November 13-18, 1962
(127 pages, numerous figures, 4 tables)

This paper discusses the history and the future of expandable structures in space applications. This disucssion covers the areas of inflatable balloons, rigidized balloons, Goodyear airmat, foamed-in-place-expandable honeycomb, and unfurlable structures in the areas of concept description, actual applications, materials, generalized design procedures, future applications, advantages, and the disadvantages of each system. It is pointed out that there is no one universal expandable structure system that will meet the requirements of all applications. However, recommendations are made concerning specific applications for each of the above-mentioned six concepts.

49526 SYSTEM REQUIREMENTS AND THE EVOLUTION OF FUTURE MISSILE SYSTEMS. H. T. Ponsford, Douglas Aircraft Company, Inc., Santa Monica, California. American Rocket Society Paper No. 2715-62 presented at the 17th Annual Meeting and Space Flight Exposition, Los Angeles, California, November 13-18, 1962 (18 pages, 5 figures)

The purpose of this paper is to consider the requirements for future missile systems in the light of political and technical conditions likely to exist in the future. After a brief discussion of the elements of military strength, unclassified trends in the technologies useful to missiles are examined to determine the bases for the evolution of missile weapon systems. Some possible future missile systems are described briefly to support the conclusion that missiles will be even more important to our national survival in the future than they are today.

Coatings

49291 See Nickel Base.

49325 METHOD OF TEST FOR HYDROGEN EMBRITTLEMENT DUE TO ELECTROLYTIC CADMIUM PLATING. B. G. Johnson, The Boeing Company, Wichita, Kansas. Paper No. 61 presented at the American Society for Testing and Materials Meeting, Los Angeles, California, October 1-5, 1962
(4 references, 22 pages, 6 figures)

The purpose of this paper is to present the results of an investigation of a method for comparing the relative tendencies of various cadmium plating processes to cause hydrogen embrittlement. The test selected for investigation was the sustained load test of cadmium plated notched test specimens. AISI 4340 steel heat treated to the 260-280,000 psi tensile strength level was selected as the test material. Button-heat type notched test specimens with notch root radii of 0.001, 0.003, 01005, and 0.025 inch were tested to determine the maximum sensitivity to hydrogen embrittlement.

49405 FLUIDIZED BED COATS REFRACTORY METALS. Chemical & Engineering News, v. 40, no. 41, October 8, 1962, p. 46 & 48
(2 pages)

Research has shown that a fluidized bed may be one of the answers to coating refractory metals. Pfaudler's research group has successfully coated molybdenum and niobium using fluidized bed technology. And one of the company's long range objectives is to use a fluidized bed to coat tungsten and tantalum.

49515 INVESTIGATION OF HIGH EMITTANCE COATINGS TO EXTEND THE MACH NUMBER RANGE OF APPLICATION OF STRUCTURAL MATERIALS. A. Gravina and M. Katz, Republic Aviation Corporation, Farmingdale, New York. WADD TR 60-102, March 1961, Contract No. AF 33(616)-5925, AD 262083
(143 references, 198 figures, 4 tables)

The value of knowing and being able to modify the thermal emittance of structural materials employed in space and missiles work is well known. This report describes the design and assembly of an apparatus capable of measuring the total and spectral normal emittance of solids at temperatures from 400 to 1800 F, and pressures from atmospheric to less than 5 microns Hg.

Caramic, paint, oxide, and metallic coatings applied to Inconel X, A-286 steel, and 6 Al-4V titanium were investigated.

Emittance data are presented for materials tested after short term, prolonged, and cyclic temperature exposures in the noted temperature and pressure range of the instrument. The effect of contamination is also considered for some materials.

It is shown that the emittance of metal substrates can be appreciably altered by the application of suitable coatings.

49531 See Nonmetallics.

Applications

49268 See Engineering Steels.

49274 DEVELOPMENT OF LIGHT WEIGHT HIGH-TEMPERATURE STRUCTURES PHASE I - DESIGN CRITERIA. E. H. Nickell and A. B. Burns, Lockheed Aircraft Corporation, Sunnyvale, California. Interim Technical Documentary Report, ASD TDR 7-938 (I), October 1962, Contract No. AF 33(657)-9145
(13 references, 64 pages, 27 figures, 3 tables)

The purpose is to establish a design criterion for high-temperature foil-gage sandwich structures and to design such a structure for fabrication. The structural efficiency of sandwich construction is compared with conventional-stiffened and unstiffened construction. The theoretical methods for predicting buckling of sandwich facing and core for specific loadings are modified by the experimental results of other investigators. These modified methods are utilized to design an optimum sandwich panel. The proposed experimental program to evaluate the applicability of these analytical and fabrication methods for foil-gage high-temperature materials is also included.

Phase I of the program was devoted to the detail design of the foil-gage light-weight structures which will be manufactured in Phase II and experimentally evaluated in Phase III. The following factors influenced design: thermal environment, time at temperature, selection and availability of materials, manufacturing ability, and structural efficiency. On the basis of efficiency studies of structures subjected to compression, shear, and normal loadings, honeycomb-sandwich construction was selected as the foil-gage configuration yielding minimum weight. Since this structure must withstand exposure to 2000 F for two hours, superalloys and refractories were prominent candidate materials. From among these materials which can be obtained commercially in foil gages, pure molybdenum, coated with protective metals or alloys, was selected for the facings, and Inconel 702 for the core.

The theoretical methods used to predict the various modes of buckling in the structure were reviewed and compared with empirical methods and the available test data. Those methods most closely agreeing with the test data were used in the design.

49285 See Carbon Graphite.

49286 See Titanium.

49289 See Refractory Metals.

49334 GAMMA SCINTILLATION SCANNING FOR INSPECTING SOLID ROCKET MOTORS. P. E. Underhill, Aerojet-General Nucleonics, San Ramon, California. Paper No. 74 presented at the American Society for Testing and Materials Meeting, Los Angeles, California, October 1-5, 1962
(8 pages, 3 figures)

A report on the development of the scanning technique now used at the Aerojet-General Corporation Sacramento plant to inspect the Polaris missile is presented. The title of the device is GIGI, which stands for Gamma Inspection of the Grain Integrity. This paper presents a brief review of

49334 (Continued)

the research and development which went into designing the gamma inspection cubicle now in operation at the Sacramento plant. The parameters involved in the development of this grain inspection system, the analytical approach, and the physical variables encountered will be considered.

49349 See Titanium.

49351 See Miscellaneous.

49352 See Miscellaneous.

49354 See Light Metals.

49357 See Carbon Graphite.

49362 See Tantalum.

49363 See Columbium.

49476 See Composites.

49477 See Ceramic Oxide.

49478 See Nonmetallics.

49504 See Miscellaneous.

49507 See Composites.

49525 LARGE CHEMICAL BOOSTERS OF TOMORROW. C. J. Wang, Aerospace Corporation, El Segundo, California. American Rocket Society Paper No. 2720-62 presented at the 17th Annual Meeting and Space Flight Exposition, Los Angeles, California, November 13-18, 1962
(5 references, 9 pages, 11 figures, 1 table)

This paper first examines the possible future need for large space boosters. The practicability of large chemical boosters is then discussed from the standpoint of structural efficiency and engine development; and the potential cost advantage of using such vehicles is established. Finally, a chemical booster of a gross weight of a hundred million pounds is postulated and discussed with respect to its configuration, payload, and cost. It is concluded that such a booster system would be desirable and practical.

49527 UNCONVENTIONAL NOZZLES. V. Ilsen, Aerojet-General Corporation, Sacramento, California. American Rocket Society Paper No. 2709-62 presented at the 17th Annual Meeting and Space Flight Exposition, Los Angeles, California, November 13-18, 1962
(6 pages, 13 figures)

Some considerations about the shapes and performance of various types of the annualr nozzles are presented here. The influences of the skirt contour and the throat setting have been investigated for several cases.

49528 DESIGN CONSIDERATIONS FOR LOW THRUST ROCKETS. M. L. Chazen, Bell Aerosystems Company, Buffalo, New York. American Rocket Society Paper No. 2705-62 presented at the 17th Annual Meeting and Space Flight Exposition, Los Angeles, California, November 13-18, 1962
(17 pages, 7 figures)

The design considerations for low-thrust rockets are primarily a function of vehicle and missile requirements which dictate the use of low thrust for attitude control and secondary-propulsion systems. The two primary modes of operation for this use are pulse mode and continuous operation. Thermal, dynamic, and radiation environments must be considered with respect to reliability in the design of rockets for pulse mode or continuous operation. The most important types of rocket cooling are regenerative, ablation, heat sink and radiation. This report is restricted to the considerations utilized in the design of low-thrust rockets incorporating radiation cooling or ablation cooling since these modes of cooling have the most general applications.

49532 See Composites.

49534 PROBLEMS UNIQUE TO LARGE DIAMETER SOLID PROPELLANT ROCKET MOTOR CASES. L. E. Gatzek, North American Aviation, Inc., Downey, California. September 12, 1962, Paper presented at the SAE National Aeronautic and Space Engineering Meeting, Los Angeles, California, October 8-12, 1962
(8 pages)

Technical analyses of factors influencing the design, selection of materials, and fabrication of a large solid-propellant motor case have been made. Limiting criteria of tooling, machining, and heat treating facilities are most significant.

Composites

49270 EFFECT OF BASIC PHYSICAL PARAMETERS ON ENGINEERING PROPERTIES OF INTERMETALLICS - PART III. J. H. Westbrook and D. L. Wood, General Electric Company, Schenectady, New York. WADD TR 60-184, July 1962, Contract No. AF 33(616)-7714
(35 references, 31 pages, 16 figures, 5 tables)

An increased hardness of grain-boundary regions above that of the bulk material is found to exist generally in intermetallic compounds having a stoichiometric excess of active-metal component. This hardening is shown to be associated with the anomalously high brittle-ductile-transition temperature in these materials, and to be related to the "pest" phenomenon. The presence of adsorbed oxygen and/or nitrogen in grain-boundary regions is found to be responsible for the increased hardness in these areas; the precise manner in which the resistance to plastic deformation is increased in this phenomenon is not clear. The effect can be modified, however, by ternary-solute additions and to some extent by appropriate annealing treatments.

49348 ULTRASONIC INSPECTION AND EVALUATION OF PLASTIC MATERIALS. W. C. Hitt and J. B. Ramsey, Automation Industries, Inc., Torrance, California. Paper No. 3, presented at the American Society for Testing & Materials Meeting, Los Angeles, California, October 1-5, 1962
(17 pages, 11 figures, 2 tables)

Some progress has been made in the ultrasonic nondestructive testing field in evaluating such properties of plastic materials as delaminations, bond condition, material thickness, and bond strength.

In this presentation, some of these applications and areas for potential applications are discussed.

49355 ADHESIVES FOR CRYOGENIC APPLICATIONS. M. B. Smith and S. E. Susman, Narmco Research & Development Corporation, San Diego, California. Society of Automotive Engineers, Inc., New York, New York. Paper No. 582C presented at the National Aerospace Engineering & Manufacturing Meeting, Los Angeles, California, October 8-12, 1962
(6 pages, 9 figures, 4 tables)

A literature survey on existing commercial adhesives suggested for very-low-temperature application demonstrated the superiority of the nylon-epoxy adhesives. A series of most promising existing adhesives was selected and evaluated more completely at very low temperature, again demonstrating the superiority of the nylon-epoxy systems.

Development work was aimed at adhesive systems applicable to field application and included filler and expansivity studies, metal-surface preparations, and composite-adhesive studies. Three adhesives were developed which demonstrate an excellent coverage of the program's target objectives. Extensive data are presented for these three developed adhesive systems.

49363 See Chromium.

49400 See Nonmetallics.

49473 SYMPOSIUM ON FIBROUS MATERIALS. Directorate of Materials & Processes, Wright-Patterson Air Force Base, Ohio. Preprint of Proceedings of Symposium, Dayton, Ohio, October 16-17, 1962
(numerous pages, numerous figures, numerous tables)

This report contains the papers to be presented at the Fibrous Materials Symposium held October 16-17,1962 at the Dayton Biltmore Hotel. The purpose of this symposium is to review and report significant accomplishments on the contractual and internal research programs sponsored by the Fibrous Materials Branch of the Nonmetallic Materials Laboratory.

49476 CONVERSION OF HIGH MODULUS MATERIALS INTO FLEXIBLE FABRIC STRUCTURES. M. J. Coplan and W. D. Freeston, Jr., Fabric Research Laboratories, Inc., Dedham, Massachusetts. Paper presented at the Symposium on Fibrous Materials, Dayton, Ohio, October 16-17, 1962
(14 references, 23 pages, 7 figures)

The designs of numerous re-entry drag or lift-drag devices incorporate a flexible, low porosity, thermally durable membrane. The missions anticipate temperatures in the range of 1500-2500 F and strengths of 20-50 pounds per inch width. The necessity of being able to package and subsequently deploy these devices demands a membrane with good bending recovery.

The possible flow patterns over and heat transfer to a porous, fibrous structure in a re-entry environment were examined. The expressions for a theoretical estimate of the heat transfer increase to the structure were developed. Unqualified statements of the precise heat transfer increase as a function of structure are not possible in light of the obvious need for experimental verification. However, the theoretical investigation indicates that a moderate porosity can be tolerated under some flight conditions without a significant temperature increase.

49507 A CASE WINDING SYSTEM FOR LARGE ROCKET MOTORS. E. E. Hardesty, Swedlow Inc., Los Angeles, California. No. A37-62116 3008, November 1962
(4 references, 15 pages)

Considerable interest has been evidenced in the necessity for obtaining a machine capable of applying, by filament winding techniques, the exterior structural shell to a solid-propellant rocket motor, either segmented or one-piece casting.

This document presents a proposal for such a piece of equipment.

Various candidate systems and methods are discussed as a preface to the resultant system selected. The basic philosophy presented stresses fabrication of propellant-encompassing filament-wound structural shells without rotating or in any way disturbing the assembled segments or one-piece casting of solid propellant; of completing the fabrication of this outer shell at or near the launch site or on the launch pad and of moving the entire winding machine - from around the completely assembled solid motor - for subsequent re-erection at another launch, or adjacent assembly, site.

49507 (Continued)

Structural, mechanical, electronic and powered drive mechanisms are explained in reasonable detail, along with recommended geometry for filament-winding patterns, as well as several systems of resin chemistry for achieving final polymerization of the binder resin without heat damage to the in situ cast propellant. Detailed design drawings are offered, as well as the availability of a working model to demonstrate coincident and simultaneous mechanical motions and functions.

49532 FILAMENT WOUND VESSELS FOR SPECIAL REQUIREMENTS. B. Levenetz, Narmco Research & Development Corporation, San Diego, California. Paper presented at the SAE National Aeronautic and Space Engineering Meeting, Los Angeles, California, October 8-12, 1962
(4 pages, 13 figures)

Three specific applications of filament winding for very specialized requirements are discussed in this paper. (1) lightweight battery; (2) ultra light rocket motor case; (3) cryogenic tank. Problems associated with filament winding are discussed at length in this paper.